Developing method for assessing particle size based sediment budget in a headwater catchment

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INTRODUCTION

Headwater catchment holds significant roles to contribute sediment supply to downstream because of direct sediment supplied from the hillslopes to channels (Gomi et al., 2002). For instance, Lehre (1982) stated that 1.7 km^2 Small Coast Range drainage basin in North-Central California produced 903 t/km^2/yr of sediment caused by persistent soil mass movement processes on hillslopes.

Sediment supplied and transports had also been examined using the sediment budget method (Walling and Collins, 2008). Sediment budget method is defined as a mass balance calculation of sediment produced from slopes, storage through channels, and transported to catchment outlet (Swanson et al., 1982). Swanson et al. (1982) indicated that the most important component in sediment budget was the recognition and quantification of transport processes, storage element, and the lingkages between them. Hence, the previous studies primarrily focused on total mass (quantity of sediment), particle sizes (quantity of the sediment) of sediment was not been incorporated into sediment budget concept. Changes in particle size distribution from supply, storage, and deposition was not been examined.

Particle size distribution is closely related to sediment delivery processes (Lisle, 1995). Lisle (1995) pointed out that particle size of bed material was consistently greater than bedload material. In 2 ha of headwater streams in southeast Alaska, Gomi and Sidle (2003) showed that fine sediment within 1 to 11 mm in diameter tended to be transported, while coarse sediment larger than 200 mm in diameter was stored in the channels.

Despite the importance for understanding the importance of particle sizes in headwater catchments, changes in particle sizes distributions from supply to transport was not been examined. Particle size distribution produced from hillslopes to channels might be different (Attal and Lave, 2006). Likewise, sediment to the catchment outlet might also differ to in-channel storage depending on discharge capacity, material composition, and channel morphology (Hiraoka et al., 2015). Therefore, the objective of this study was for developing methods of particle size based sediment budget in headwater catchments. For archiving this objective, we firstly assessed particle size distribution of hillslope and channels for developing sediment budget in a small headwater catchment.

STUDY SITE AND METHODOLOGY

This study was conducted in a 7.0 ha headwater catchment within the Oborasawa watershed (Fig.1). Annual precipitation and mean temperature was 3000 mm and 12^{o}C, respectively (Oda et al., 2013). Mean hillslope gradient was 36^o and mean gradient of stream bed was 0.52% (Hiraoka et al., 2015). Underline geology of catchment was Cenozoic sedimentary rock (Oda et al., 2013).

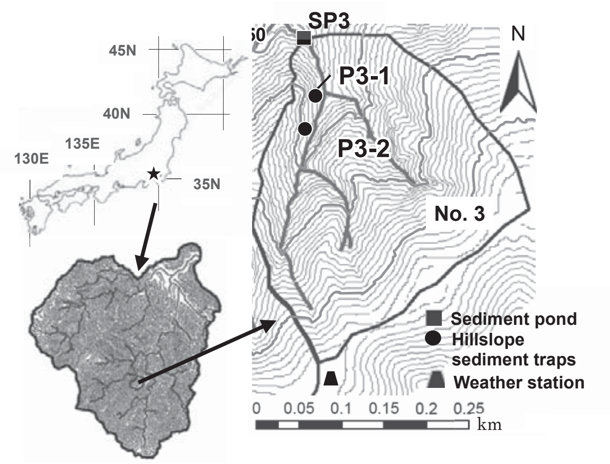

Fig.1 Study site in Oborasawa watershed

Sediment supplies from hillslopes were collected by sediment traps with 1 m width. Sediment and litter was collected every one to two month. At the catchment outlet, all transported sediment was collected by a weir pond. Sample of sediment in the weir pond was also collected every one to two month. We also measured amount of sediment deposit by monitoring survey (Hiraoka et al., 2015). All samples were sieved using 40, 25, 9.52, 4.00, 2.38, 0.84, 0.59 mm in diameter. We also measured three axis diameters for the maximum particle of each sample in hillslope plots and the weir pond.

RESULTS AND DISCUSSIONS

(1) Supplied sediment from hillslope

Sediment sample was analysed from two different observation periods, in the summer period from June 5 to July 23, 2015 (SP) and the autumn period from September 15 to November 6, 2015 (AP) (Fig.2). Amount of mean sediment supplied in summer and autumn were 77 g/days and 39 g/days, respectively. For two plots, P3-2 tended to produce 14 times greater amount of sediment than P3-1. Total rainfalls during the period were 877 mm in SP and 233 mm in AP. Maximum 24hr precipitation in the summer and autumn periods were 337 and 60 mm/day, respectively. In the sediment traps, 8 g/days of litter (5% of total sample) was collected in SP, while 9 g/days of litter (10% of total sample) was collected in AP.

The maximum diameter supplied in SP was 69 mm with 20 mm of D_{50} and 40 mm of D_{90}. The maximum particle in AP became 78 mm with 30 mm of D_{50} and 40 mm of D_{90}.

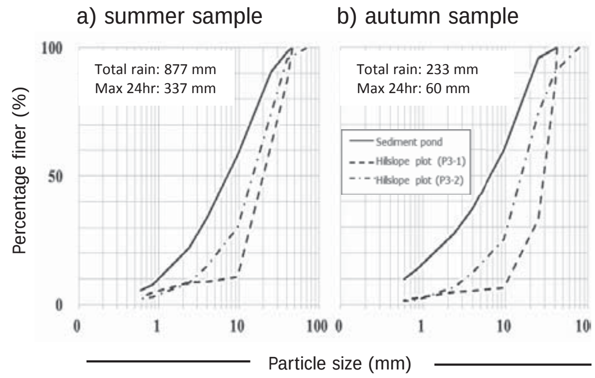

Fig.2 Cumulative frequency of particle size in (a) Summer and (b) Autumn samples.

Smaller particle produced in the summer period than in the autumn period was associated with different mechanism of sediment production in these seasons. High and intense precipitation in summer was triggering rain drop impacts and splash soil erosion (Nanko et al., 2008). Soil sheet erosion may also produce on hillslope with low infiltration capacities (Wohl, 2000). On the other hands, during the periods of the late autumn, freezing and thawing can produce coarse particle size (Oztas and Fayetorbay, 2003).

Sediment supply was also varied in particle size for each plot. P3-1 tended to produce coarse particle than P3-2. Therefore, D_{50} and D_{90} in P3-2 was 18 to 54 % smaller than that in P3-1. P3-1 was surrounded by exposed surface rock and soil compared to P3-2. P3-2 tended to have less litter coverages on soil surface. Therefore, P3-2 had high chance for soil erosion for producing fine sediment than in P3-1.

(2) Transported sediment in a channel

Particle size of sediment in the catchment outlet was similar between the summer and autumn samples. D_{50} and D_{90} in the sediment pond of SP were 7 and 23 mm, respectively. Maximum diameter in the summer sample was 45 mm. In the autumn sample, D_{50} and D_{90} in sediment pond were 6.5 mm and 22 mm. Maximum diameter in the autumn sample was 42 mm.

Sediment particle in sediment ponds was consistently smaller than that in supplied sediment in hillslopes. This finding agrees to the other findings by Gomi and Sidle (2003) and Hiraoka et al. (2015). Based on the transport particle size less than 10 mm, only 10 to 30% of supplied sediment was transported directly to downstream. Findings of our study indicated that most of sediment supplied on hillslope deposited within the channel and accumulated. Such accumulated sediment was either weathered or transported by extremely large event (Gomi and Sidle, 2003).

CONCLUSION

Our findings in a headwater catchment showed that particle size based understandings is essential for sediment budget concept. Our findings also showed that seasonal differences of sediment particles in hillslope plots associated with changes in dominant mechanisms of sediment supply. For further investigation, we need to examine full range of sediment supply and transport of both particle size and amount. Estimating amount of in-channel sediment storage and their particlue size is also necessary for completing the sediment budget as mass balance calculation to identify the volume changes of sediment yields associated by particle size from headwater catchments.

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Keyword: developing method, particle size, particle distribution, sediment budget, headwater catchment